

Chapter 4. Groundwater

4.1 Introduction

Kentucky's groundwater is an important source of drinking water for more than 1.7 million Kentuckians, as well as a source of water for industry and irrigation. An estimated 1,537,595 Kentuckians are served by 185 public water systems (PWSs) that rely on groundwater (Figure 4.1-1), in whole or part, as their source. An additional 415,950 rural Kentuckians not connected to public water systems rely on private wells, springs, and other sources (e.g. cisterns) for their drinking water (Table 4.1-1). Groundwater also contributes significant recharge to streams. Protection of this resource is crucial to Kentucky's economy, public health and the environment.

Figure 4.1-1. Groundwater sources for public water suppliers in Kentucky.

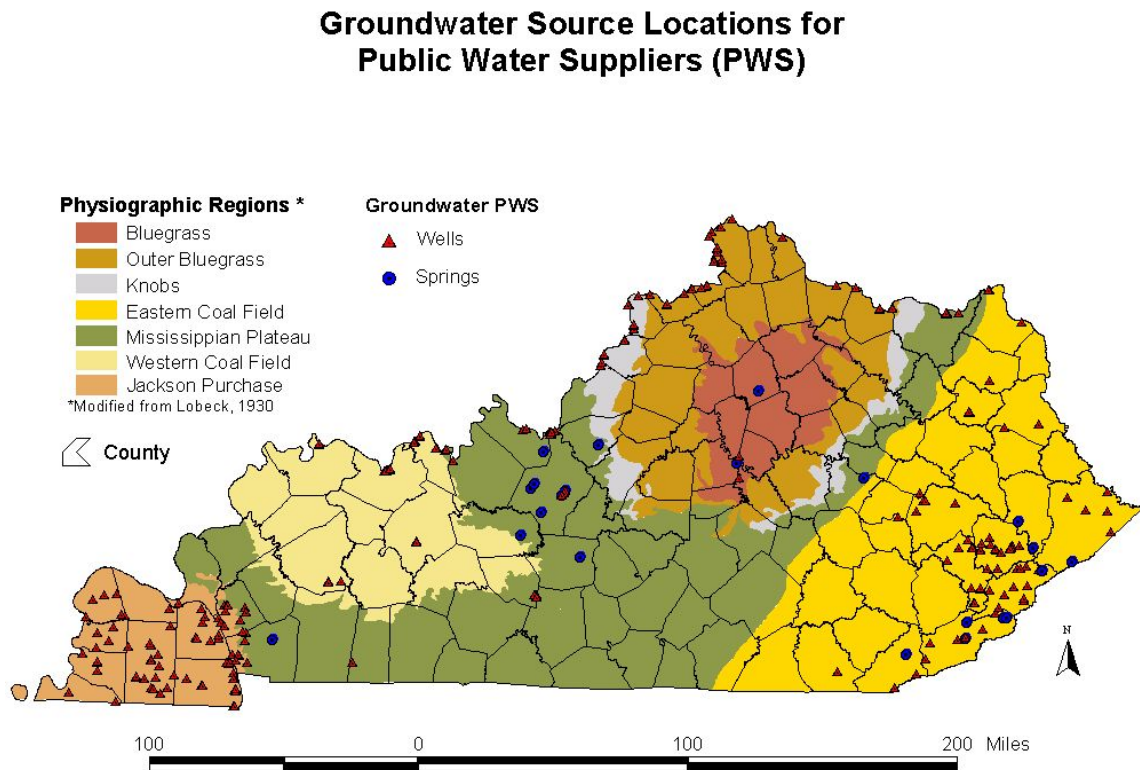


Table 4.1-1. Estimates of state population served by public water and private sources.

Year 2000	Population 2005	% of State Population 2005	% Population on Potable Water Sources in 2005 ¹	Population 2000	% of State Population 2000	% Population on Potable Water Sources in 2000 ¹	Population 1990	% of State Population 1990	% Population on Potable Water Sources in 1990 ¹
# Service Connections	1,537,595	N/A	N/A	1,350,788	N/A	N/A	1,214,664	N/A	N/A
Population Served	3,751,732 ²	90.06%	90.06%	3,512,049 ²	86.89%	86.89%	2,970,717	80.61%	80.61%
Population not served by Community PWS's ⁵	415,331	9.97%	4.34% ⁴	529,720	13.11%	7.21% ⁴	714,578	19.30%	10.66% ⁴
Population on private wells	293,690	7.05%	3.07% ⁴	374,547	9.27%	5.23% ⁴	505,254	13.71%	7.75% ⁴
Population on private springs & other sources	122,475	2.94%	1.28% ⁴	155,173	3.84%	2.17% ⁴	209,324	5.68%	3.21% ⁴
State Population	4,165,814 ⁶	100.00%	95.65%	4,041,769 ³	100.00%	94.29%	3,685,296	100.00%	91.57%
Total	4,165,814 ⁶	100.00%	95.65%	4,041,769 ³	100.00%	94.29%	3,685,296	100.00%	91.57%

1. "Potable" traditionally means that water which poses no appreciable health risk (via pathogens or chemicals) for consumption. The assumption in this model is that all public water is "potable," however some public water systems do have occasional problems with Maximum Contaminant Levels, (MCL) violations. Also, some public water systems fail secondary (non-enforceable) standards relating to taste and odor. These failures to meet secondary standards can be related to variations in source water quality, and problems with treatment or the distribution system. Problems with public water systems (PWS) meeting secondary standards can be ongoing, but are more commonly occasional or intermittent. The Division of Water works with these systems to address secondary standard violations in order to bring these PWS's into compliance. For wells, springs, and other sources, other aesthetic considerations such as color, taste, and odor were considered in addition to pathogen or other contaminant issues in resolving the estimate of the number of people with access to potable drinking water sources.
2. The population served by Community Public Water Systems in 2000 is calculated by multiplying the total number of service connections by 2.6. $N \times 2.6 = PS$, where N = the number of service connections, and PS = the estimated population served. The multiplier (2.6) represents the average number of people served per service connection. N is estimated at 2.44 for 2005⁶.
3. Number available from U.S. Census Bureau 2000.
4. Based on Departmental studies, approximately 43.5percent of all wells tested exceed the secondary standard for Iron. These studies tested pre-treatment water only and this number does not include water that is successfully treated via domestic treatment systems to meet or exceed primary and secondary standards. As the secondary standard for iron was the most common "potability" problem for private sources we determined that this consideration would be the most conservative estimator of access to potable private sources. Please note that a well, spring, or cistern may have one or more conditions that effect the potability of the water.
5. Population not served by Community PWS's includes private wells, springs, cisterns, and hauled bottled water.
6. Estimated population for the year 2005 by the U of L Kentucky State Data Center.

Definitions: 1) "Community Public Water Systems" are public water systems serving an average of ≥ 25 people/day year-round, or systems with ≥ 15 service connections; 2) "Service connections" are individual homes and businesses connected to Community Public Water Systems; 3) "Other sources" are springs, cisterns, and hauled water; and 4) "Potable water" is water produced by any Community Public Water System, and domestic/private water supplies which meets both the Primary Maximum Contaminant Levels and the Secondary Maximum Contaminant Levels

4.2 Availability and Use

Naturally occurring potable groundwater is found throughout Kentucky, although quantities available for use vary considerably, as controlled by regional geological characteristics. Kentucky's groundwater resources occur in four aquifers types: 1) alluvial deposits in the Ohio and Mississippi river valleys and other major stream valleys; 2) karst aquifer systems of the Pennyroyal and Bluegrass regions; 3) unconsolidated sediments of the Jackson Purchase area; and 4) fractured bedrock aquifers of the Eastern Kentucky and Western Kentucky Coal Fields.

High-yielding wells constructed in alluvial deposits are typical of the Ohio and Mississippi river valleys that comprise Kentucky's northern and western borders. Wells in these valley aquifers are the most productive of any wells in the Commonwealth, producing adequate high-quality water for domestic, public, industrial and agricultural use. Much of Kentucky's future drinking water needs will be met by these aquifers, as evidenced by a recent increase in use of the aquifers by public water systems rather than surface water sources. This trend is being driven, in part, by new, more stringent surface water treatment rules and the cost to treat.

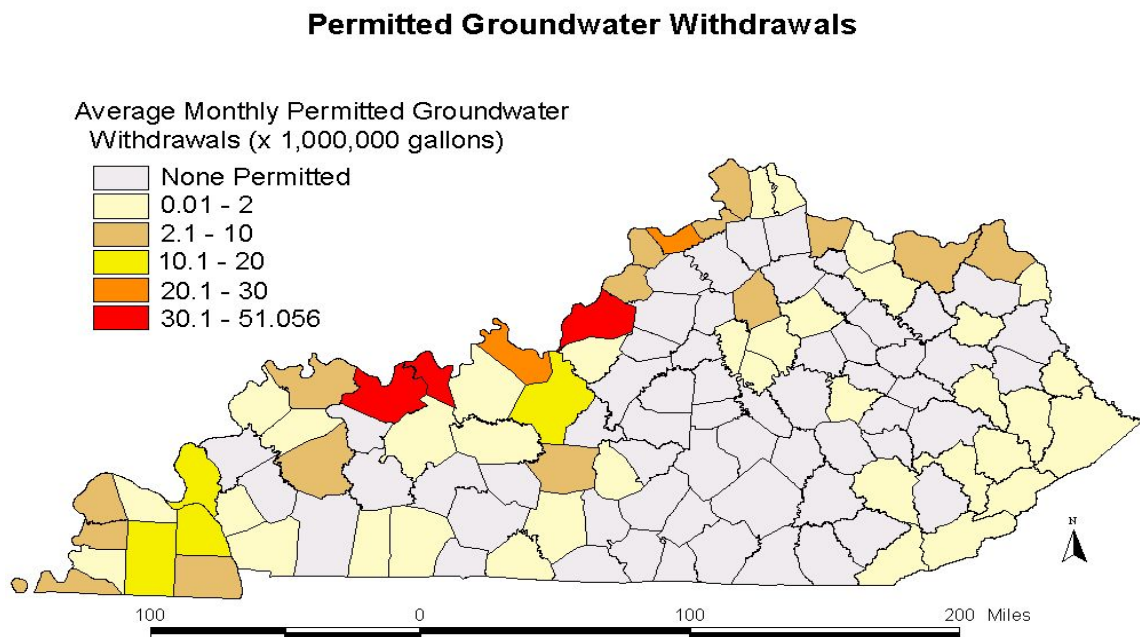
Karst aquifers, developed in soluble rocks (e. g. limestone and dolomite) are characterized by numerous shallow conduit-flow systems of generally limited extent. Approximately 50 percent of Kentucky is underlain by karst aquifers. The most extensive karst aquifers are in the Pennyroyal region of western Kentucky. Karst aquifers are present, but less well developed, in the Inner Bluegrass region. The availability of groundwater in karst areas is highly variable and generally supports public and domestic supplies. Locally, karst groundwater may support agriculture and industry.

In the Western Kentucky and Eastern Kentucky Coal Field regions, wells in fractured sedimentary rocks generally provide sufficient water for domestic use, and locally provide sufficient water for smaller public water systems. The unconsolidated sediments of the Jackson Purchase region are prolific aquifers, supporting widespread domestic, industrial and agricultural use, as well as public water systems (PWSs).

In 2005, 36 percent of PWSs in Kentucky depended upon groundwater, in whole or part, as a source, withdrawing more than 70 million gallons per day total (Figure 4.2-1). The majority of PWS's use is from the alluvial deposits along the Ohio River and

unconsolidated sediments in the Jackson Purchase region. Numerous PWSs in eastern Kentucky are supplied by water wells and a number of PWSs in the Pennyroyal and Bluegrass utilize natural springs. Households that depend upon private water wells for their drinking water are most numerous in eastern Kentucky and in the Jackson Purchase region; these two regions account for about 75 percent of all new well construction in the state. Approximately 415,331 people depend on private sources for their drinking water, primarily from private wells and springs (Table 4.2-1). The number of people on private sources is decreasing as PWSs expand to previously unserved areas.

Figure 4.2-1. Permitted groundwater withdrawals in Kentucky.

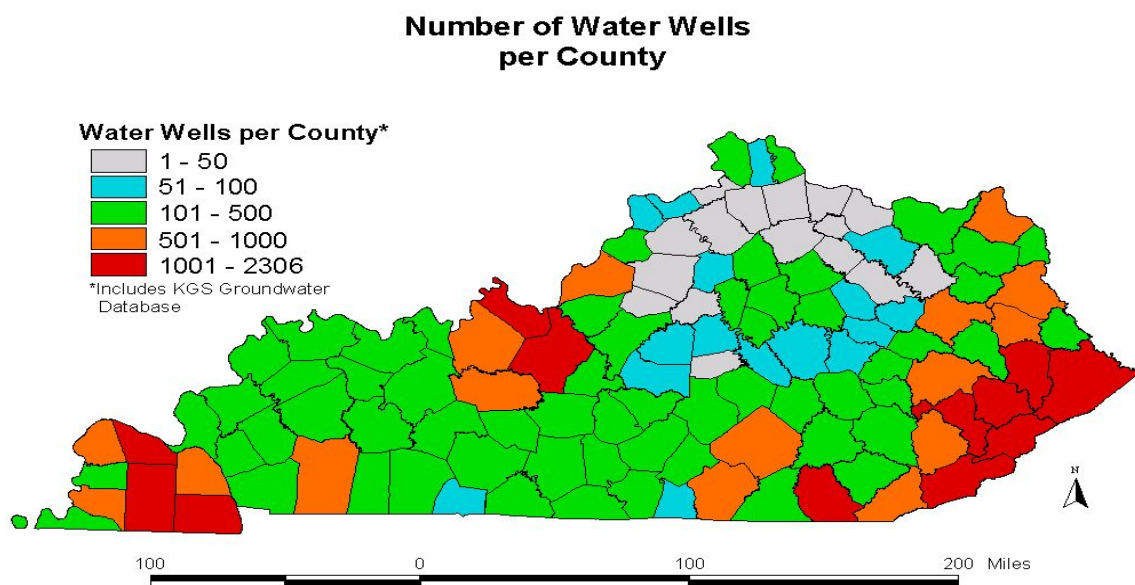


4.3 Groundwater Quality

In Kentucky, water wells are found in every county (Fig. 4.3-1) and the quality of groundwater used for private domestic supplies is generally good, although there are areas of the state where local water quality problems exist. Common, naturally occurring groundwater quality problems include pathogens, elevated levels of nitrates, iron, sulfur,

and “hard” or “salty” water due to high total dissolved solids (TDS). Of these contaminants, nitrates and pathogens represent potentially serious, acute health risks if levels above maximum contaminant levels (MCLs) is regularly consumed, especially by unborn children, infants, and those vulnerable to infection or other health impacts (e. g., the very young, elderly, and immune-compromised people).

Figure 4.3-1. Number of water wells per county in Kentucky.



Pathogens, indicated by the presence of coliform bacteria, generally occur in wells because of improper construction or maintenance. Exposure to pathogens normally manifests itself with gastro-intestinal problems and flu-like symptoms, however some pathogens can have much more serious consequences. Pathogens can be introduced into wells from local soils if well construction fails to meet the established standards, including the required amount of casing, sealing of the annulus, and the proper set-backs from potential sources of contamination such as septic systems. Pathogens may also occur in the well because of a failure to disinfect the well after maintenance, or failure to maintain sanitary seals. Well disinfection after construction, pump removal, etc. by a certified driller is required, and the KDOW strongly recommends that well owners routinely inspect, disinfect, and sample their wells for bacteria. Although this is not

difficult, and guidance is readily available from the KDOW and other sources, most well owners fail to do this.

Elevated nitrates (greater than 10 parts per million $\text{NO}_3\text{-N}$) do occur locally, principally in shallow wells, or in springs, where sources of nitrate (e. g. fertilizer application, manure storage/application, animal feedlots) are prevalent. Elevated nitrates are known to cause methemoglobinemia in infants (“blue baby” syndrome). This illness is caused by the conversion of nitrate to nitrite in the blood, which reduces its ability to carry oxygen, thus causing cyanosis, a bluish discoloration of the skin, and in severe cases, death.

Iron and sulfur, common in many of Kentucky’s aquifers, do not typically represent health risks, but if elevated these parameters can affect the aesthetic quality of water including taste, odor, and staining of clothes, appliances and plumbing.

Elevated TDS in groundwater occurs naturally in some areas, but may also result from historic oil and gas drilling and production. Elevated TDS is largely an aesthetic concern, causing “hard” water and scaling in pipes and appliances. At higher levels, water may taste “salty” and be variously objectionable to many people.

4.3.1 Contamination Issues

Groundwater quality in Kentucky is generally good; water quality is directly related to land use, geology, groundwater sensitivity and well construction. Nonpoint source impacts on groundwater quality are primarily from agriculturally related nutrients and pesticides. Major sources of groundwater contamination in Kentucky are listed in Table 4.3.1-1.

Nitrates are a widespread concern, especially in shallow wells constructed in alluvial and coastal plain aquifers and in karst springs. Nitrates impact these aquifers because recharge in these areas is sufficiently rapid so that attenuation of nitrates is not complete in the upper soil horizons. The principal sources of nitrates in these aquifers are from agricultural activities including fertilizer application, manure storage and application, and animal feeding operations. Elevated nitrates have impacted a small number of PWSs relying on groundwater. In addition, shallow, private wells are more likely to have elevated nitrate.

Table 4.3.1-1. Major sources of groundwater contamination.

Contamination Source	Eleven Highest Priority Sources (X)	Factors Considered in Selecting a Contaminant Source (See Below) (Use all that apply)	Contaminants (See Below) (Use all that apply)
Agricultural Activities			
Agriculture Chemical Facilities			
Animal Feedlots	X	I, III, V, VI, VII	B, E, J, K, L
Drainage Wells			
Fertilizer Applications	X	I, III, IV, V, VI, VII	E
Irrigation Practices			
Pesticides Applications	X	I, III, IV, VI, VII	A, B
On-farm Agricultural Mixing and Loading Procedures			
Land Application of Manure (unregulated)			
Storage and Treatment Activities			
Land Application			
Material Stockpiles			
Storage Tanks (above ground)			
Storage Tanks (underground)	X	I, III, IV, V, VI, VII	C, D, H
Surface Impoundment			
Waste Piles			
Waste Tailings			
Disposal Activities			
Shallow Injection Wells (Class V) – includes stormwater runoff from urban and agricultural land uses.	X	I, II, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, J, L, M (Sediment)
Deep Injection Wells			
Landfills, including pre-law landfills	X	I, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (Leachate Compounds)
Septic Systems	X	I, II, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, J, K, L
Other			
Dry Cleaners	X	I, III, IV	C (TCE)
Hazardous Waste Generators			
Hazardous Waste Sites			
Industrial Facilities	X	I, III, IV, V, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (TCE)
Material Transfer Operations			
Mining and Mine Drainage	X	I, III, IV, V, VI, VII	G, H, M (Sediment runoff, dewatering wells)
Oil and Gas wells/operations		III, IV, VI, VII	G, H
Pipelines and Sewer Lines			
Salt Storage and Road Salting			
Salt Water Intrusion			
Spills	X	I, II, III, IV, V, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (TCE)
Transportation of Materials			
Various (e.g. drums wire-burners, battery crackers)			B, C, D, H,
Small-Scale Manufacturing and Repair Shops			
Factors I- Human Health and/or environmental risk (toxicity) II- Size of the population at risk III- Location of the Sources relative to drinking water sources IV- Number and Size of contaminant source V- Hydrogeologic Sensitivity VI- State Findings, other Findings VII- Best Professional Judgment		Contaminants A- Inorganic Pesticides B- Organic Pesticides C- Halogenated compounds D- Petroleum compounds E- Nitrate F- Fluoride G- Salinity / Brine H- Metals I- Radionuclides J- Bacteria K- Protozoa L- Viruses M- Other (see narrative)	

Pesticides are also a concern, especially in karst areas coincident with major agricultural and urban areas where use of herbicides on row crops is prevalent in the former, and domestic lawn and garden chemicals are commonly applied in the latter. In karst areas, pesticides bypass soil attenuation processes and contribute to elevated levels in karst groundwater systems. These aquifers, in turn, discharge pesticide contaminated water to surface water systems in an efficient fashion, as groundwater and surface water in karst terrain are conjunctive. Although pesticide concentrations in groundwater are often elevated seasonally, detections and significant levels are not limited to application season. Atrazine is the most commonly detected pesticide, but only limited detections occur above the MCL of 3 parts per billion. Two PWSs have experienced compliance problems with atrazine.

Urban growth and land use also impact karst aquifers. Urban sprawl threatens some karst aquifers, particularly where new growth does not coincide, as is common, with the extension of sewers. The additional hydrological loading from concentrated septic systems exasperates collapse potential forming sink basins, and the increased hydrologic, pathogen, nutrient, and pesticide loading typical of urban areas can degrade groundwater quality in karst and other regions. Further, improperly managed injection of storm water into karst aquifers in urban areas also impacts local groundwater and surface-water quality.

Local contamination from landfills, USTs, Superfund sites and hazardous waste sites remains a concern as much for Kentucky as for other states. However, no widespread impacts or negative trends on ambient water quality resulting from waste sites have occurred in Kentucky. The occurrence of MTBE and BTEX is largely limited to contaminated sites; occasional minor detections of BTEX and MTBE in urban karst springs are likely the result of storm water runoff. Disruption of groundwater use in both private and public water supply wells and springs because of contamination has occurred locally, but is uncommon. There are currently 1,405 sites with known or suspected groundwater contamination, including 1,116 UST sites, 45 solid waste sites, 202 state and federal Superfund sites and 42 hazardous waste sites (Table 4.3.1-2). The department is tracking contaminated groundwater sites and the condition of groundwater at these sites. Kentucky has recently developed a broad-based remediation program that applies to

Table 4.3.1-2. Local contamination from landfills, USTs, Superfund and hazardous waste sites. Date of data shown: (1-1-04) to (12-31-05).

Source Type	Number of Sites		Number of Sites with Confirmed Releases	Number of Sites with Groundwater Contamination	Contaminants	Source
NPL	19		19	19	PCBs, SVOCs, VOCs, Metals, Inorganics, Pesticides, and Radionuclides	Division of Waste Management (DWM) Superfund Branch State Superfund Section – Hubbard
State Sites	1,029		1,066	138		
CERCLIS						
Non-UST Petroleum	176		250	45	Petroleum	
UST	4,314		2,472	1,116	BTEX, PAH, Lead	DWM - UST Branch – Terry
RCRA Corrective Action	87	RCRA-D 45	45	45	Organics	DWM - Solid Waste Branch- Pilcher
		RCRA-C 63	36	36	Cyanide, PCBs, VOCs, ABNs, PAHs, Metals, and Radionuclides	DWM - Hazardous Waste Branch – Jung
DOD/DOE	6	6	6	6		
UIC	Total	Class I 1	N/A	N/A	Varied	Robert Olive -EPA
		Class II 3,897				
		Class V 467				

Contaminants: PCB- Polychlorinated Biphenyl BTEX- Benzene, Toluene, Ethylene, and Xylene, SVOC- Semi Volatile Organic Compound, PAH- Poly Aromatic Hydrocarbons, VOC- Volatile Organic Compound and ABN- Acid Base Neutral

contaminated sites, including brownfields. Over the next several years, this program should significantly reduce the number of contaminated sites.

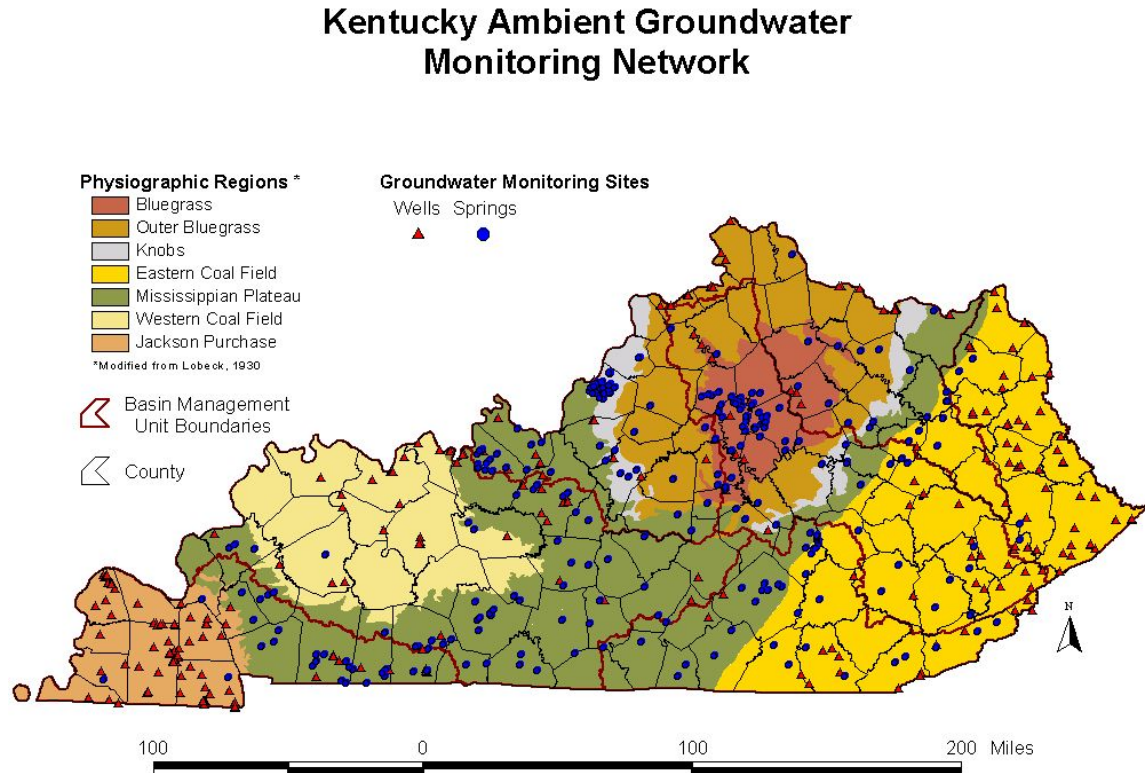
4.4 Ambient Groundwater Quality Monitoring

The Division of Water has collected and analyzed approximately 4,000 groundwater samples from about 500 sites to characterize ambient groundwater conditions and nonpoint source impacts (Figure 4.4-1). Sites are usually sampled from one to six times per year, based on aquifer type and monitoring goals. However, two projects are underway that will assess groundwater in karst areas based on surface water protocols, which may be more appropriate for these systems that can directly and profoundly influence surface water quality. Water quality parameters evaluated include nutrients, major inorganic ions, total and dissolved metals, pesticides and volatile organic compounds, including MTBE. Analysis of groundwater for pathogens is a major logistical challenge, but the division has addressed this issue in several assessment projects and is improving.

A summary of the results of ambient groundwater monitoring for major parameters of concern in Kentucky is presented in Table 4.4-1. Water quality trends seem to be related to regional geology, land use, groundwater sensitivity (Figure 4.4-2) and well construction. Anthropogenic impacts on groundwater quality occur predominantly in the most sensitive (karst) areas, primarily from agricultural activities. Persistent localized groundwater contamination from human activities occurs around pre-law landfills, leaking underground storage tanks, poorly maintained septic systems, direct discharge of waste through “straight pipes” to karst aquifers, historic oil and gas production, mining operations and drainage, and urban runoff. Less persistent, but still of concern locally, are spills and contamination from industrial facilities. Urban storm-water runoff is an increasing concern, particularly in karst areas where storm-water is commonly managed via Class V Underground Injection Control wells.

Results. Specific groundwater quality standards have not been adopted in Kentucky; however, other appropriate standards are applicable to assess impacts to groundwater. Generally, we assume the highest use of groundwater: that the groundwater is being consumed without any treatment, as hundreds of thousands of

Figure 4.4-1. Kentucky ambient groundwater monitoring network.



Kentuckians do. Therefore, drinking water standards are generally used as a comparative standard for groundwater quality. Drinking water standards include maximum contaminant levels (MCLs), and secondary (aesthetic) standards (SMCLs), both promulgated for the drinking water program that regulates PWSs. In addition, for elements or compounds that do not have an MCL or SMCL, a health advisory level (HAL) is used as a comparative standard. Some impacts to groundwater, such as those from nonpoint sources, may be significant, but well below any health or aesthetic concerns. Therefore, it is appropriate to use reference groundwater conditions as a comparative standard for assessing these types of impacts.

Table 4.4-1. Ambient water quality monitoring results for reporting period 2004 – 2005.

Suite	Constituent	MCL (mg/L)	Number of Sites	Sites with Detects	Sites w/ Detects < ½ MCL	Sites w/ Detects ≥ ½ MCL	Sites w/ Detects > MCL	Number of Samples	Non- Detects	Detects < ½ MCL	Detects ≥ ½ MCL
Other	Fluoride	4	203	147	146	1	1	472	129	342	1
	Nitrate (as N)	10	203	192	159	33	9	472	25	351	96
	Nitrite (as N)	1	203	12	12	0	0	472	459	13	0
RCRA Metals	Arsenic	0.010	219	79	75	4	1	497	378	115	4
	Barium	2	219	219	215	4	2	497	0	493	4
	Cadmium	0.005	219	2	2	0	0	497	495	2	0
	Chromium	0.1	219	124	124	0	0	497	196	301	0
	Copper ¹	1.0	219	212	211	1	0	497	68	428	1
	Iron ¹	0.3	219	129	68	89	69	497	265	93	139
	Lead	0.015	219	91	88	3	2	497	377	115	5
	Manganese ¹	0.05	219	193	141	82	58	497	60	311	126
	Mercury	0.002	218	9	9	0	0	496	487	9	0
	Nickel ²	0.1	219	147	146	1	1	497	271	225	1
	Selenium	0.05	219	110	109	1	0	497	306	190	1
	Silver ^{1 2}	0.1	219	25	25	0	0	497	471	26	0
	Zinc ¹	5	219	184	183	1	1	497	164	332	1
PCB	Aroclor 1016	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1221	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1232	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1242	0.0005	193	1	1	0	0	462	461	1	0
	Aroclor 1248	0.0005	193	1	0	1	1	462	461	0	1
	Aroclor 1254	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1260	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1262	0.0005	193	0	0	0	0	462	462	0	0
	Aroclor 1268	0.0005	193	0	0	0	0	462	462	0	0
Pesticides	Acetochlor ³	0.055	165	0	0	0	0	352	352	0	0
	Alachlor	0.002	165	3	3	0	0	352	349	3	0
	Atrazine	0.003	165	37	36	1	0	352	297	54	1
	Atrazine desethyl	0.003	165	33	33	0	0	352	297	55	0

Table 4.4-1 (cont.). Ambient water quality monitoring results for reporting period 2004 – 2005.

Pesticides (cont.)	Constituent	MCL (mg/L)	Number of Sites	Sites with Detects	Sites w/ Detects < ½ MCL	Sites w/ Detects ≥ ½ MCL	Sites w/ Detects > MCL	Number of Samples	Non- Detects	Detects < ½ MCL	Detects ≥ ½ MCL
Pesticides (cont.)	Cyanazine ²	0.001	165	0	0	0	0	352	352	0	0
	Metolachlor ²	0.1	165	13	13	0	0	352	335	17	0
	Simazine	0.004	165	7	7	0	0	352	343	9	0
SVOC	Anthracene ³	0.830	179	10	10	0	0	371	360	11	0
	Benzo(a)anthracene ³	0.000034	179	9	0	9	8	371	361	0	10
	Benzo(a)pyrene	0.0002	179	13	10	3	1	371	354	14	3
	Fluorene ³	0.110	179	51	51	0	0	371	319	52	0
	Naphthalene ²	0.1	219	1	1	0	0	481	480	1	0
VOC	Benzene	0.005	221	4	4	0	0	483	478	5	0
	Chlorobenzene ³	0.017	219	1	1	0	0	481	479	2	0
	Dichloromethane (Methylene chloride)	0.005	219	17	17	0	0	481	463	18	0
	Ethylbenzene	0.7	221	3	3	0	0	483	480	3	0
	Methyl-tert-butyl ether (MTBE) ³	0.05	219	3	3	0	0	481	478	3	0
	Tetrachloroethane (1,1,1,2-) ²	0.07	219	0	0	0	0	481	481	0	0
	Tetrachloroethene ³	0.010	219	19	18	1	0	481	449	31	1
	Toluene	1	221	7	7	0	0	483	476	7	0
	Trichloroethane (1,1,1-)	0.2	219	18	18	0	0	481	463	18	0
	Trichloroethene	0.002	219	8	6	2	0	481	472	6	3
	Vinyl chloride	0.002	219	2	2	0	0	481	478	3	0
	Xylene (1,2-)	10	221	3	3	0	0	483	480	3	0
	Xylene (1,3- & 1,4-)	10	221	3	3	0	0	483	480	3	0

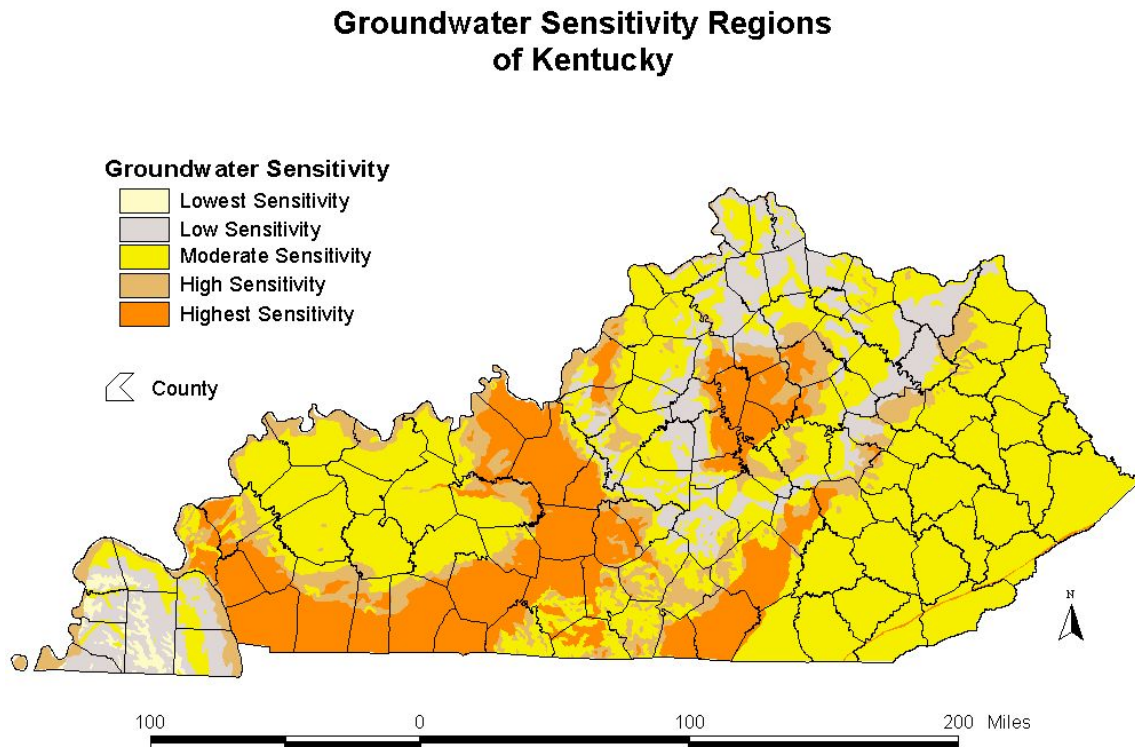
¹ SDWR

² HAL

³ DEP standard

These standards used where MCL unavailable

Figure 4.4-2. Groundwater sensitivity regions of Kentucky.



Results: Inorganics. Fluoride is common in much of Kentucky as the mineral fluorite, and its presence in groundwater is also common; 73 percent of 472 samples collected over the reporting period had detections of fluoride. Only 1 sample exceeded the MCL of 4 mg/L. Fluoride is important in the development of healthy teeth and bones, but too much can cause dental and skeletal fluorosis.

Results: Nutrients. As noted above, low levels of nitrate occur naturally in groundwater. Elevated nitrate (more than its MCL of 10 mg/L) in drinking water can cause health problems, specifically methemoglobinemia. Nitrate was detected in 89 percent of samples, with 40 samples exceeding the MCL. However, preliminary results of on-going research focusing on shallow wells in agricultural areas indicate that there may be a more widespread problem with nitrate in shallow groundwater.

Results: Metals. Arsenic was detected in approximately 24 percent of ambient samples but was detected above its MCL of 0.010 mg/L only once. Arsenic is naturally

occurring in groundwater, and its occurrence may be related to iron reducing bacteria in these wells.

Lead, a metal found in natural deposits, may also be found in household plumbing materials and water service lines. Although lead is not commonly detected in groundwater, it is sometimes detected in samples as a result of its leaching from plumbing and service lines, typically from older lead-based solder or pipes containing lead, which are no longer approved for potable water applications. Lead was detected in 24 percent of 497 samples, but exceeded the action level of 0.015 mg/L in only three samples. Nevertheless, lead is a significant health risk at even mildly elevated levels and needs to be addressed when present in significant concentrations.

In groundwater, iron and manganese are common naturally occurring metals. Of 497 samples, the majority detected both metals, with 19 percent of iron and 15 percent of manganese exceeding their respective SMCLs. Iron and manganese can cause significant aesthetic issues including color, taste, odor and staining issues.

Zinc is commonly detected in groundwater, but rarely at elevated levels. Of 497 samples analyzed for zinc, 67 percent detected some zinc, but only one exceeded the SMCL. Silver is rarely found in groundwater in Kentucky. Of 497 samples analyzed for silver, there were 26 detections and no samples exceeded the SMCL. Elevated levels of both of these metals generally result from the leaching of service lines and plumbing materials.

Results: Pesticides and PCBs. Polychlorinated bi-phenyls (PCBs) were detected in three of the 462 samples analyzed for these potent carcinogens, with one sampling exceeding the MCL. Many of the more widely-used herbicides were often detected in many samples, the most common being atrazine, with lesser occurrences of alachlor, metolachlor, and simazine. Generally, these agricultural pesticides occur only in karst springs coincident with intensive row-cropping and rarely exceed established health-based standards. Atrazine does appear to be more persistent in groundwater, occurring in 16 percent of 352 samples analyzed, with no detections above MCL. Metolachlor and simazine were infrequently detected and never above MCL. In addition, traces of several domestic use pesticides are routinely detected, especially in urban areas

developed on karst terrain, such as Louisville (Jefferson Co.) and Lexington (Fayette Co.).

Results: SVOCs. Semi-volatile organic compounds do not normally occur naturally in groundwater and therefore their occurrence in ambient sampling is rare. Benzo(a)anthracene was detected in 8 of 371 samples (two percent) above MCL and benzo(a)pyrene was found in 1 of 371 samples (< one percent) above its MCL. The most frequently detected SVOC was fluorine, which was found in about 14 percent of 371, but was not detected at levels above the MCL. The source of these detections is anthropogenic, principally fuels, such as gasoline and diesel fuel. Although these detections are rarely above drinking water standards, their presence does suggest impacts from point sources, such as leaking underground storage tanks, and nonpoint sources, such as storm-water runoff.

Results: VOCs. Volatile organic compounds were not detected above MCL during the reporting period. Trace amounts of several of these compounds were infrequently detected. For example, tetrachloroethene was the most frequently detected volatile organic compound and was found in 31 of 481 samples (six percent), and the second most frequently detected compounds were trichloroethane (1, 1, 1, 2-) and dichloromethane, which were both found in 18 of 481 samples (four percent).

4.5 Groundwater Quality and Public Water Systems

The KDOW has collected and analyzed untreated groundwater samples at numerous (22) public water systems (PWSs) to characterize groundwater conditions including point and nonpoint source impacts to groundwater supplying those systems. This monitoring effort supports both the ambient groundwater monitoring program and the wellhead protection program, providing PWSs valuable information about the quality of and threats to their supplies. A summary of the results of ambient groundwater monitoring for major parameters of concern in Kentucky is shown in Table 4.5-1. Groundwater quality at PWSs is exceptional, which is critical, as the majority of these systems do not treat their source water other than disinfection.

Table 4.5-2 illustrates the corresponding data for finished water (water distributed to customers) at PWSs using groundwater as source, either in whole or part. For 25

Table 4.5-1. Ambient (raw) water quality results for PWS sites, reporting period 2004 – 2005.

Constituent	MCL (mg/L)	PWS Sites Only					Samples				
		Number of Sites	Sites With Detects	Sites w/ Detects < ½ MCL	Sites w/ Detects ≥ ½ MCL	Sites w/ Detects > MCL	Number of Samples	Non- Detects	Detects < ½ MCL	Detects ≥ ½ MCL	Detects > MCL
Fluoride	4	22	16	16	0	0	25	6	19	0	0
Nitrate (as N)	10	22	20	18	2	2	25	3	19	3	2
Nitrite (as N)	1	22	3	3	0	0	25	22	3	0	0
Arsenic	0.010	22	8	8	0	0	25	16	9	0	0
Barium	2	22	22	22	0	0	25	0	25	0	0
Cadmium	0.005	22	0	0	0	0	25	25	0	0	0
Chromium	0.1	22	9	9	0	0	25	15	10	0	0
Copper ¹	1.0	22	21	21	0	0	25	2	23	0	0
Iron ¹	0.3	22	11	4	8	8	25	13	4	8	8
Lead	0.015	22	9	8	1	0	25	16	8	1	0
Manganese ¹	0.05	22	17	10	8	7	25	5	12	8	7
Mercury	0.002	22	1	1	0	0	25	24	1	0	0
Nickel ²	0.1	22	14	14	0	0	25	10	15	0	0
Selenium	0.05	22	9	9	0	0	25	15	10	0	0
Silver ^{1,2}	0.1	22	0	0	0	0	25	25	0	0	0
Zinc ¹	5	22	20	19	1	1	25	2	22	1	1
Aroclor 1016	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1221	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1232	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1242	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1248	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1254	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1260	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1262	0.0005	22	0	0	0	0	25	25	0	0	0
Aroclor 1268	0.0005	22	0	0	0	0	25	25	0	0	0
Acetochlor ³	0.055	18	0	0	0	0	19	19	0	0	0
Alachlor	0.002	18	0	0	0	0	19	19	0	0	0
Atrazine	0.003	18	1	1	0	0	19	18	1	0	0
Atrazine desethyl	0.003	18	0	0	0	0	19	19	0	0	0
Cyanazine ²	0.001	18	0	0	0	0	19	19	0	0	0
Metolachlor ²	0.1	18	0	0	0	0	19	19	0	0	0

Table 4.5-1 (cont.). Ambient (raw) water quality results for PWS sites, reporting period 2004-2005.

Simazine	0.004	18	0	0	0	0	19	19	0	0	0
Anthracene ³	0.830	18	3	3	0	0	19	16	3	0	0
Benzo(a)anthracene ³	0.000034	18	0	0	0	0	19	19	0	0	0
Benzo(a)pyrene	0.0002	18	0	0	0	0	19	19	0	0	0
Fluorene ³	0.110	18	9	9	0	0	19	10	9	0	0
Naphthalene ²	0.1	22	0	0	0	0	25	25	0	0	0
Benzene	0.005	22	0	0	0	0	25	25	0	0	0
Chlorobenzene ³	0.017	22	0	0	0	0	25	25	0	0	0
Dichloromethane (Methylene chloride)	0.005	22	0	0	0	0	25	25	0	0	0
Ethylbenzene	0.7	22	0	0	0	0	25	25	0	0	0
Methyl-tert-butyl ether (MTBE) ³	0.05	22	0	0	0	0	25	25	0	0	0
Tetrachloroethane (1,1,1,2-) ²	0.07	22	0	0	0	0	25	25	0	0	0
Tetrachloroethene ³	0.010	22	0	0	0	0	25	25	0	0	0
Toluene	1	22	1	1	0	0	25	24	1	0	0
Trichloroethane (1,1,1-)	0.2	22	0	0	0	0	25	25	0	0	0
Trichloroethene	0.002	22	0	0	0	0	25	25	0	0	0
Vinyl chloride	0.002	22	0	0	0	0	25	25	0	0	0
Xylene (1,2-)	10	22	0	0	0	0	25	25	0	0	0
Xylene (1,3- & 1,4-)	10	22	0	0	0	0	25	25	0	0	0

¹ SDWR

² HAL

³ DEP standard

} These standards used where MCL unavailable

Table 4.5-2. Finished drinking water data at PWSs for groundwater systems

For period of 1-1-04 to 12-31-05							
# of Sites	Parameter Group	Total # of Analyses	# of Non-detects <MDL	# of Detects >MDL to <MCL	Less than 1/2 MCL <=5	5 to <=10	Greater than the MCL
92	VOC	4,861	4,848	13	-----	-----	0
47	SOC	2,458	2,426	32	-----	-----	0
97	IOC	1,603	1,328	249	-----	-----	26
149	NO ₃	344	64	-----	280	47	0

samples collected at 22 PWSs, MCL exceedances were infrequent. Nitrate was found above MCL in two samples, and zinc in one. The only volatile organic compound detected was toluene, which was found in one sample at less than half its MCL. Iron and manganese are common naturally occurring constituents in many aquifers, and SMCLs were exceeded in eight of 25 iron samples and seven of 25 manganese samples. Atrazine was detected in trace amounts in one of 19 samples. PCBs and SVOCs were not detected.

In finished water samples at PWSs sourced by groundwater, no VOC, SVOC or nitrate detections exceeded MCLs. Twenty-six of 1,603 (1.6 percent) samples exceeded standards for IOCs.

4.6 Monitoring Resource Issues

Although Kentucky is among the nation's leaders in coordinating its groundwater activities through its Interagency Technical Advisory Committee, additional resources are necessary to improve efforts to characterize our groundwater. Routine monitoring should expand to better capture regional and temporal trends and conduct additional aquifer characterization for pathogens, pharmaceutically active compounds and other emerging pollutants. In addition, expanded mapping of some aquifers is needed to better assess aquifer quantity. Significant resources have been invested to implement new technologies and consolidate data management, but additional resources are necessary to expand groundwater education and public outreach.

4.7 Groundwater Protection Programs

Kentucky has established or is maintaining many programs that protect the Commonwealth's groundwater resources (Table 4.7-1). Three programs are highlighted in the following.

Ambient Groundwater Monitoring Network. Since 1995, the KDOW has about 4,000 groundwater samples at approximately 500 sites as part of the state's ambient groundwater monitoring program aimed at characterizing ambient groundwater conditions and nonpoint source impacts to groundwater. Monitoring sites included public and private water supply wells and springs, unregulated public access springs (i. e. "roadside springs"), and unused springs. About 70 sites comprise the current ambient network and these sites are sampled from one to six times per year, depending on aquifer type. Samples are analyzed for a number of water quality parameters, including nutrients, major inorganic ions, total and dissolved metals, pesticides, and volatile/semi-volatile organic compounds. Each year the KDOW also collects groundwater samples for several nonpoint source assessment projects funded through Section 319(h) of the CWA as part of ongoing watershed-based initiatives. In addition, the KDOW conducts quarterly groundwater monitoring at four sites under an agreement with the Division of Pesticide Regulation (DOPR) as part of their FIFRA grant work plan. The ambient monitoring program supports the Groundwater Protection Plan and Wellhead Protection programs by providing a resource-quality tracking measure and providing raw water data to several PWSs using groundwater. Also, ambient network data are used by the solid waste, hazardous waste, Superfund and UST programs to characterize ambient, or "background", conditions and identify potential problems.

Groundwater Protection Plan Program: Kentucky's Groundwater Protection Plan regulation requires that entities conducting activities that have the potential to pollute groundwater develop and implement a groundwater protection plan. The plan must include pollution prevention activities such as preventative maintenance and best management practices, spill response plans, record keeping, training and regular inspections to ensure that the protective practices are in place and functioning properly. For agricultural activities, Kentucky's Agricultural Water Quality Plan outlines mandatory best management practices that help prevent pollution of the state's waters.

Table 4.7-1 Groundwater protection programs^a

Programs or Activities		Implementation Status	Responsible State Agency
Active SARA Title III Program		Continuing Efforts	Department for Environmental Protection Commissioner's Office
Ambient Groundwater Monitoring System		Continuing Efforts	Division of Water
<i>Aquifer Vulnerability Assessment</i>		N/A	N/A
Aquifer Mapping		Ongoing	Kentucky Geological Survey/Division of Water
Aquifer Characterization		Ongoing	Kentucky Geological Survey/Division of Water
Coal and Non Coal Mining Regulations	✓	Established	Division of Mine Reclamation and Enforcement
Comprehensive Data Management System		Established	Division of Water
<i>EPA-endorsed Core Comprehensive State Ground-Water Protection Program (CSGWPP)</i>		N/A	N/A
Groundwater Discharge Permits		Continuing Efforts	EPA Region IV
Groundwater Best Management Practices		Established	Division of Conservation
Groundwater Legislation		Implemented	Division of Water/Kentucky Geological Survey
<i>Groundwater Classification</i>		N/A	N/A
Groundwater Protection Program		Established	Division of Water
Groundwater Quality Standards	✓	Developing	Division of Water
Groundwater Sensitivity Mapping		Complete	Division of Water
Interagency Coordination for Groundwater Protection Initiatives		Established	Interagency Technical Advisory Committee Watershed Steering Committee
Kentucky Pollution Discharge Elimination System (KPDES)	✓	Established	Division Of Water
Kentucky Voluntary Environmental Remediation Program	✓	Established	Division of Waste Management
Non-Point Source Controls		Established	Division of Water
Pesticides State Management Plans		Developing	Division of Pesticides
Pollution Prevention Program		Implementing	Division of Water
Oil and Gas Regulations	✓	Established	Division of Oil and Gas
Resource Conservation and Recovery Act (RCRA) Primacy		Established	Division of Waste Management
Safe Drinking Water Act and 1986 , 1996 Amendments	✓	Established	Division of Water
Source Water Assessment Program		Continuing Efforts	Division of Water
State Superfund		Established	Division of Waste Management
State RCRA Program Incorporating more Stringent Requirements than RCRA Primacy		N/A	N/A
State Septic System Regulations		Established	Cabinet of Health Services

Table 4.7-1 (cont.). Groundwater protection programs^a

Programs or Activities	Implementation Status	Responsible State Agency
Underground Storage Tank Installation Requirements	Established	Division of Waste Management
Underground Storage Tank Remediation Fund	Established	Division of Waste Management
Underground Injection Control Program	Fully Established	EPA Region IV
Vulnerability Assessment for Drinking Water/Wellhead Protection	Completed	Division of Water
Well Abandonment Regulations	Continuing Efforts	Division of Water
Wellhead Protection Program (EPA-approved)	Established	Division of Water
Well Installation Regulations	Continuing Efforts	Division of Water

^aItalicized programs are N/A (Not Applicable) at this time

Wellhead Protection Program: Kentucky's Wellhead Protection program requires that PWSs using a groundwater source develop a wellhead protection plan for their source water. A wellhead protection plan is designed to delineate the recharge area of the well(s) or spring(s), identify potential contaminant sources in the recharge area and implement groundwater protection strategies for these areas. Kentucky's wellhead protection program is a fundamental part of its Source Water Assessment Program (SWAP), as required by the 1996 Amendments to the Safe Drinking Water Act. Kentucky has been a national leader in source water protection, and was the first state in the nation to have its SWAP approved by the USEPA.

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